CHAPTER THREE

DESIGN SURVEYS

BUREAU OF DESIGN AND ENVIRONMENT

SURVEY MANUAL

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Table of Contents

Page

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I. INTRODUCTION

The design survey that establishes the alignment on the ground and obtains the data necessary to prepare the construction plans is discussed in this chapter. It is assumed that adequate location work has been performed to determine the general horizontal alignment on paper and now this line must be reproduced on the ground. The problems encountered are different depending on whether the alignment is on existing location or on new location. Both cases will, therefore, be treated separately.

II. ALIGNMENTS

A. GENERAL

All alignments consist of curves and/or tangents. The majority of the curves used in highway work are simple curves that are merely arcs of a circle used to unite two tangents differing in direction. The length and radius of the curve to be used must be in accord with the policies enumerated in Volume II, Chapter 31 of the Bureau of Design and Environment Manual based on the design speed of the proposed improvement. Curve data is not required at PI's where the central angle between tangents is less than 15 minutes. See Appendix A for curve information.

B. ALIGNMENTS ON EXISTING LOCATION

Many surveys are performed for the purpose of rehabilitating an existing highway. Such a project normally involves horizontal or vertical realignment or regrading the section and, therefore, a survey of the existing features is necessary. In general, this type of survey will attempt to reproduce the original centerline.

A set of prints of the original plans is very helpful on this type of survey, not only for reestablishing the line, but also for locating topographical features that should be recorded. The survey should be started on, or as close as possible to, the original stationing. The original survey stationing may or may not be used at the discretion of the surveying agency. In some cases, the beginning of the original section may be very apparent. Station numerals in the pavement should not be used to establish the stationing for a survey but will provide an approximate check on the original stationing. If neither of these are available, a topographical feature such as a bridge, culvert or a fence line may be used. In any case when reestablishing an existing line, it should be checked at more than one location.

To establish alignment on tangents, the pavement is “split”. This is done by digging down alongside the edges on both sides of the pavement until a good vertical face is uncovered. The distance from edge to edge is then measured and the pavement centerline is marked at the midpoint. The same procedure is repeated farther down the road so a total station instrument or theodolite may occupy one point and sight on the next to establish centerline. This procedure will produce a series of straight lines with slight deflection angles between the tangents. The angles, however, are far too small to cause any difficulty.

At horizontal curves, the construction plans should be consulted to obtain the existing curve data. The first step in locating the centerline on the curve is to establish the PI by extending the tangents found by the method described previously. The angle of the PI should then be measured as well as the apparent external and tangents. A curve meeting these conditions is then run in. If the centerline thus produced does not fit the existing pavement satisfactorily, some adjustment in the curve data may be necessary.

With the alignment established in the manner described above, the line is measured and stationed. The stations are marked at 100 foot intervals and the alignment is established with the aid of a Total Station. The station markings can be made with a nail or “redhead” in blacktop or gravel. A “redhead” is simply a nail which has been driven through a strip of “doubled over” red cloth or ribbon.

A chisel mark or masonry nail is used on concrete. A dab of bright colored paint with the last digit of the station on each mark and a full painted station number every 500 feet will prove to be very helpful as the remainder of the survey is completed. Marked laths along a fence line are most useful in locating stations at a later date.

C. ALIGNMENTS ON NEW LOCATION

The procedure used in establishing line on a new location will vary somewhat from the method described previously. The crew chief is generally furnished with data or information derived from the location survey. This information will indicate the paper location of the line and various control features or points. Normally, stakes would have been placed only at the transit stations during the first run of the line, although laths may have been used to mark the locations of the line as it crosses fences. These laths in the fence lines are very helpful to anyone trying to find the line at this stage of the design.

A coordinate system is used in determining the paper location of an improvement. The primary system used is the Illinois State Plane Coordinate System. (See Chapter 2, Section III, page 2-11). The control used can come from NGS monuments directly or it can be from a special control survey. In either case, coordinates for the control points (generally PI's) can be computed and furnished to the survey crew. The first run of the line using this method should produce a satisfactory alignment, although minor corrections can still be expected.

If the line established on the first run is satisfactory, or would be satisfactory with only minor corrections, the final line may be established. The final horizontal line should be field checked and approved by a designated representative of the District Engineer prior to completing the survey. This line should be run in accordance with "third-order" surveying procedures. (See Chapter 2, Section II, page 2-5). Stakes are normally placed at every station and should be marked with the station number. Iron pins should be placed and referenced at all stations where instrument setups were made. The length of the pin and the depth it is buried will depend on frost conditions. Pins in cultivated fields should always be buried at least 18 inches (0.5 meters). A note should be made of the depth buried. Guard stakes or laths should be used at transit points and should be marked with the station and the description of the point (i.e., POT, PI, etc.). Curves should be staked out in accordance with the procedure contained in Section E, page 3-4. Stationing shall be established to run from south to north and from west to east.

D. REFERENCE POINTS

The points used to establish the tangent alignment should be established as POT's and, along with PC's, PI's and PT's, should be referenced. The POT's to be referenced should be clearly intervisible. Wherever possible, at least two of the reference points should be located beyond the anticipated construction limits, except where distances to such reference points would be excessive. Reference ties should also include Illinois State Plane Coordinates for the alignment point. At least four reference ties should be used for each point. Recognizing the temporary nature of such points, a nail and washer are often used on trees, fence posts and utility poles as the point to which the reference tie is measured. Stakes may be used as reference points where topographic features are not available. Distances to the tie points should be measured horizontally unless otherwise noted and recorded to the nearest hundredth of a foot (0.005 meters). Tie point distances exceeding 100 feet (30 meters) are undesirable.

The ties should be recorded in the field book so that they may be shown on the construction plans. In addition to the distances to the tie points, the station of the point and the angle between the backsight and the foresight measured in the clockwise direction should be shown. The suggested method of recording "ties" is illustrated in Figure 3.1, page 3-25.

The centerline must also be tied to the U.S. Rectangular Land Survey System. This will be necessary to prepare the right-of-way plats and descriptions needed. 765 ILCS 205/9 of the Illinois Compiled Statutes requires a plat of any highway that is to be "laid out, located, opened, widened or extended, or its location altered" to be recorded in the office of the county recorder "making reference to known and established corners or monuments". Ties should, therefore, be established from the centerline to property corners, property lines, subdivision corners and corners such as section and quarter-section monuments. This subject is discussed in greater detail in Chapter V of this manual. The line should also be referenced to the State Plane Coordinate System.

E. STAKING A CURVE

E.1 Deflection Angle Method

Knowing the location of the PI, the central angle (I) and the radius (R), the PC and PT may be located by measuring the tangent distance in both directions from the PI along the respective tangent lines. The stationing of the PC is determined by subtracting the tangent distance from the stationing of the PI while the stationing of the PT is determined by adding the length of curve to the stationing of the PC. The deflection angle to any point on the curve can be computed by the equation: [d (in minutes) = 1718.873 divided by the radius in feet (meters) and multiplied by the arc length in feet (meters)]. (See Table of Deflections, Page 3-32, 33). With the instrument set up at the PC, staking the curve can be accomplished by turning the deflection angles referred to above and measuring the appropriate chord distances. As a general rule, measure chord distances of 100 feet (25 meters) for curves having a radius greater than 1900 feet (600 meters). For radii between 800 feet (250 meters) and 1900 feet (600 meters) use 50 foot (15 meter) chords, and use 25 foot (10 meter) chords for radii between 400 feet (125 meters) and 800 feet (250 meters). Other intervals may be needed to better define the curve. A notebook with a table of stations, deflection angles and chord lengths should be set up and checked before running in the curve.

Several precautions should be observed in running in a curve. When "turning off" an angle with a theodolite, errors will be magnified as the distance from the theodolite increases. To minimize these errors, the length of sight on a curve shall be limited to approximately 1000 feet (300 meters). Also, it has been found that if the angle between the tape and the line of sight is more than about 30°, the location of the point may not meet accuracy requirements. If the total deflection angle exceeds 30°, an intermediate setup or a setup at the PT should be used.

To orient the instrument at an intermediate point, back sight on the last instrument station with the telescope inverted and the plates set at the total deflection angle of the station sighted on as recorded in the notes. To continue the curve, plunge the telescope and set the plates to the total deflection angles as prepared in the original table of stations and deflections for the succeeding stations and measure the corresponding distances between them.

At the PT, the instrument may be oriented by sighting along the tangent towards the PI with the telescope normal and the plates set at the total deflection angle of the PT (i.e., I/2). To run in the curve, set the plates at the total deflection angle of each station as given in the notes and measure the corresponding distances.

Occasionally it may be necessary to run in a curve from a previous survey that had carried the stationing along the tangents. Since the distance from the PC to the PT along the curve will be less than along the tangents, an equation of stationing must be used. The original stationing should be picked up at the PC and carried around the curve and the equation placed at the PT. The equation will state, for example, that Station 103+23.80 (Back) = Station 103+29.40 (Ahead). The "back" station is the station of the PT determined by measuring along the curve and the "ahead" station is established by measuring along the tangents.

E.2 Radial Method

The total station type instrument provides another method for staking curves. Coordinate values and alignment information for a project can be stored by the total station software. After an alignment has been computed for a project, the coordinate values of the alignment are transferred electronically to the total station along with the coordinate values of other control stations in the project.

To stake a curve with a total station, select a known control point to occupy with the instrument. Select an adjoining control station to use as an azimuth to orient direction. Identify the station on the curve to be set. The total station software will compute the radial clockwise angle to be measured from the azimuth line and computes the distance from the instrument's position to the selected centerline station. Knowing the radial angle and distance, the centerline station is set by a rod person moving a range pole equipped with a prism onto and along the line of sight until the appropriate distance is attained and a marker placed at the point. All points along a centerline tangent or curve can be set using the radial procedure.

This procedure does not produce a closure check of the curve layout as does the deflection method. Extreme caution should be used when staking a centerline using the radial method. As with the deflection method, lines of sight shall be limited to 1000 feet (300 meters). When establishing points using this procedure, the results should be checked by repeating the procedure or locating them from a different location. Another method of checking is to chain between the stations that were set to check the spacing.

F. VERTICAL ALIGNMENT

F.1 Establishing A Level Datum

The crew chief shall obtain all elevation data that is available before leaving the office. Every effort should be made to utilize the National Geodetic Survey (NGS) data where it is available. Where NGS bench marks (BM) are not available, United States Geological Survey (USGS) data may be utilized. Where USGS data is used, it should be confirmed that the data is based on the North American Vertical Datum of 1988 (NAVD88). If the survey is within the corporate limits of a city that has a special datum, a tie should be made to the city datum. An assumed vertical datum should only be used in extremely isolated cases for small projects.

As mentioned earlier, a note shall be placed in the field book indicating what datum was used. The location of the bench mark with a full description, including the elevation used shall be noted. Field notes shall indicate the elevation closure on another government or known bench mark. Always use two different bench marks whenever possible, otherwise, close back to the starting bench mark.

F.2 Setting Temporary Bench Marks

Temporary bench marks should be established at not more than 1000 feet (300 meter) intervals. The bench marks should be placed in something permanent where they will not be disturbed and will be easily accessible during construction. Occasionally, there will be instances where this cannot be done. Wherever possible, avoid placing bench marks in fence posts and utility poles since they are often moved prior to construction. The most common temporary bench marks are a chiseled square in a headwall, a spike in a tree or pole and flange bolts on fire hydrants. An accurate description of each bench mark must be recorded in the notes.

F.3 The Level Crew & Notes

Running the initial level circuit and setting temporary bench marks is often done concurrently with the establishment of the horizontal alignment. The level crew is made up of an instrument person and one or two rod persons. The instrument person is in charge of the level crew and operates the instrument and keeps notes. The notes are kept in a field book or by an electronic data collector. The leveling notes are entered in a field book as illustrated in Figure 3.2, page 3-26. A sample set of level notes from a bar code level and data collector is shown in Figure 3.2a, page 3-27.

All level circuits must be closed and checked either against the initial bench mark or a second government or known bench mark before they are used for reference. The field notes must also be checked and initialed by someone other than the original note keeper.

III. TOPOGRAPHIC SURVEYS

A. PROCEDURES

After the horizontal alignment is established and the stations marked, it is necessary to record the topography. The topographic features are recorded by noting the centerline distance from the last full station as a “plus” and the right angle distance from the point on the survey centerline to the object. A right angle prism or mirror may be used to determine that the point on the survey centerline is at right angles to the object. If the survey is being made on an existing pavement, the tape person may precede the note keeper and mark the “pluses” and the distances to various objects on the pavement with keel or paint. This method is efficient since the note keeper and tape persons do not have to wait for each other. Topography data is collected also with a total station with a data collector by angle and distance measurements. This data is transferred from the data collector to a portable computer and converted to station and offsets.

When performing topographic surveys, the Survey Point Codes that have been established by the Department to standardize data collection and labeling should be used. See Appendix E of this manual for the Point Code listing and identification.

B. NOTES

The topography notes may be recorded in a separate notebook depending upon the magnitude of the project. A separate notebook for topography and cross sections will permit the data to be plotted simultaneously during the design stage. The stations are indicated on a vertical line in the center of the page with an "x" and recorded from the bottom of the page to the top of the page. In the case of curves, a curved pencil line off the tangent line should be used. Curve data are shown at the appropriate location. Notes and sketches are generally not made to scale. Symbols and abbreviations used should conform to those shown in the Highway Standards.

When one notebook is used for topography and cross-sections, the cross-section notes should be recorded on the left-hand page of the notebook and should run concurrently with the topography notes on the opposite page. The notations should always be large enough to be easily read. There are times when it is tempting to "squeeze" in some notes, but it should be kept in mind that the paper in the field book is very inexpensive compared to the time that may be wasted trying to decipher such a note. A north arrow should be shown at the beginning, ending and at intervals throughout the topography notes. A sample format for topography notes is illustrated in Figure 3.3a, b, c, page 3-28, 29, 30.

C. FEATURES TO BE RECORDED

In general, all physical features within the limits of the improvement that affect the proposed design should be recorded. The amount of data collection can be reduced significantly if a photogrammetry survey is completed. Topography should be obtained 1000 feet (300 meters) beyond the beginning and ending of the section. All features that lie 50 feet (15 meters) beyond the proposed right of way lines should be included. Any critical buildings which are within 10 feet (3 meters) and not greater than 25 feet (8 meters) outside of the approximate right of way line shall be tied to the centerline and shown on a sketch as accurately as possible. The location of all wells should be shown on the sketch.

The surveyor should definitely be instructed before the survey is made as to whether the tree removal pay item is to be in acres (hectares) or in unit-diameters where one unit is equal to one inch (25 mm). If the pay item is to be measured in acres (hectares), the approximate area limits should be identified prior to the actual survey. If the pay item is to be in unit-diameters, it will be necessary to measure the circumference of the individual trees at a point three feet (one meter) above the highest ground level at the base of the tree. To determine the diameter, divide the circumference by 3.1416. The diameter (expressed in feet) is converted into units by multiplying by twelve. If the diameter is expressed in millimeters, it is converted to units by dividing by 25. Hedgerows should be accurately located and the general size noted. The character of the adjoining land should be noted, such as: cultivated, pasture land, wooded, etc.

The location of all overhead utility lines shall be recorded together with the ownership and elevation to the low wire. Sometimes a utility pole may be jointly owned and carry more than one utility's cables or wires. Trigonometric leveling should be used to determine the height of power lines since the use of a rod or tape for this purpose is dangerous. Underground utility facilities should likewise be noted. In urban areas where manholes, inlets and catch basins are encountered, each shall be located. The location of sewers or other underground facilities shall be indicated. Elevations shall be obtained for the top and bottom of each manhole, inlet and catch basin together with the flow line of the inlet and outlet pipes. Valve vaults shall be treated similarly with the exception of the interior elevation. The utilities should be properly identified as storm sewer, sanitary sewer, water, telephone, gas, etc. **PLEASE NOTE: The Department has a Policy for entry into confined spaces that requires survey crews to take extensive safety measures when performing inspections or surveys of sewers, inlets, manholes and culverts. See Appendix D for the details of the Confined Space Policy.**

All city and village limits should be tied to the centerline by a plus distance and an angle to the limits. Angles between all apparent property lines and the centerline are to be recorded, together with the plus to the apparent property corners. All property corner pins discovered during the survey should be located and the location accurately recorded in the field book. A magnetic locator may be required for this work. Fence lines and the apparent ownership of the various tracts of land affected by the proposed improvement should be noted. Existing property fences should be measured at each station.

Information concerning side streets and side roads must be noted. A plus shall be taken and an angle measured to the centerline of all side roads. Where there are curb returns on the side streets, the radii of the curb returns and the angle that the main curb line makes with a new centerline should be recorded. The type and width of the road surface should be noted for each side road together with any available data regarding the base, the width of right of way and the name of the road or street. The profile of the side road or street should be recorded for a minimum distance of 300 feet (100 meters) in urban areas and 600 feet (200 meters) in rural areas. If any adjustments or improvements are to be done along the side road beyond the mainline right of way, it may be necessary to have cross sections on the side road centerline. To avoid confusion during the design and construction stage, crossroads and streets should be stationed in each direction from the mainline starting at 100+00 where the crossroad or street intersects the mainline centerline. Driveways shall be sketched to show the type and width of the driveway along with notes on any existing culverts. Profiles should be taken on driveways, sidewalks, water wells, cisterns and steps.

All drainage structures should be noted and arrows should be used to indicate drainage courses. Private drains, field tiles, house drains and similar underground drainage facilities must be recorded. Low points that do not drain or any other drainage problems should be noted. At bridges, culverts and railroads, special survey data are required. Section V, page 3-14 covers these special surveys in further detail.

IV. CROSS-SECTIONING

A. PROCEDURE

After the temporary bench marks have been set and the horizontal alignment and stationing have been established, the cross-sectioning can begin. This work is done utilizing a note keeper, an instrument person, two or more rod persons and one or more flag persons. The crew chief will frequently serve as note keeper.

The process of cross-sectioning is performed to obtain the necessary field data for which the volumes of earthwork may be computed. Electronic computers should be used to determine earthwork volumes. Plotted cross-sections can assist the designer in illustrating special features of the proposed improvement.

The cross-section is essentially a short transverse profile with rod readings taken frequently enough to show any change in slope of the ground that would affect the volume of earthwork or the flow of surface water. See Figure 3.4, page 3-31. The cross-section should always extend beyond the proposed right of way line or existing right of way line to facilitate the accuracy of plotting. The cross-sectioning should extend to at least 25 feet (10 meters) beyond the existing right of way line.

B. NOTES

Cross-section notes may be recorded in a separate notebook depending on the magnitude of the project. If one notebook is used for cross-sections and topography, the cross-section notes should be recorded on the left-hand page of the notebook and should be kept concurrently with the topography notes so that the stations of the two will be approximately opposite one another. In general, sections in a rural area will be taken at 100 feet (25 meters) intervals and at all breaks in the ground terrain that would affect the earthwork volumes. In urban areas, cross-sections should be taken at a maximum spacing of 25 feet (10 meters). In either case, a section must be obtained at the specified interval.

In some instances it may not be necessary to take cross-sections at every break in the centerline profile for purposes of earthwork. However, it is desirable to have a true profile and a centerline shot should be taken at every distinct break in the profile. At some locations, such as an entrance, it may be desirable to show a transverse profile on one side of the centerline only and a half section can be taken. These sections, however, cannot be used for earthwork computations, and should be marked “not for earthwork computations”.

To begin cross-sectioning, differential levels are run from the nearest bench mark to the part of the line to be cross-sectioned. The instrument should be set up under normal conditions to read approximately 300 feet (100 meters) back and ahead on each set up. Great care must be taken in the selection of the instrument location so that all, or nearly all, of the necessary readings can be obtained. Elevations should be checked with all available bench marks and should close within third-order accuracy.

Rod readings should be taken at all break points and should be read to one tenth of a foot (0.010 meters) on the dirt and to one hundredth of a foot (0.005 meters) on pavements or other permanent man made objects. Distances to culvert headwalls, pavement edges, etc. should be carefully measured and recorded to five hundredths of a foot (0.020 meters). Distances to ground shots are recorded to the nearest one foot (0.3 meters). Those points must be on a line normal to the centerline unless otherwise noted. Special care must be employed to keep the shots at right angles when they extend out beyond 50 feet (15 meters).

Cross-section data are recorded in the notes opposite the station number in fractional form with the rod reading as the numerator and the distance from centerline as the denominator. Care must be taken to record readings correctly as to the right or left of the centerline. The proper method of recording cross-section notes is indicated in Figure 3.3a, b, c, page 3-28, 29, 30.

In some situations elevation shots are required on a ground surface that is higher than the instrument. It is permissible to use a hand level to acquire the rod reading for these shots. The reading thus obtained is the distance by which the elevation of the ground exceeds the elevation of the instrument. The rod readings shall be recorded with a plus (+) sign in front of the reading to indicate the reading shall be added to the height of instrument and not subtracted from it.

If your cross-section notes run from the bottom of the page to the top, the height of instrument (HI) should be shown at the bottom of the page. If the notes run from the top of the page down, show the HI at the top of the page.

C. DIGITAL TERRAIN MODEL DATA

C.1 Introduction

Digital Terrain Modeling (DTM) is a procedure for developing a mathematical model of the terrain surface using appropriate software. It is an alternative to the conventional method of collecting cross section data along a base line. The data consists of points with known horizontal and vertical positions. The data can be collected through the use of photogrammetry or by the use of survey instruments such as: total stations and GPS receivers. Whichever procedure of collection is used, the data will consist of basically two types: breaklines and mass points.

Breaklines: Breaklines are lines consisting of data points with known “xyz” values that define linear terrain features that have a uniform slope on either side of the line. Examples are ditch lines, ridge lines, edges of pavement, etc.

Mass Points: Mass points are points with “xyz” values normally completed after the breaklines are defined and are used to fill in the areas where there are no breaklines. They are points collected on a grid pattern.

C.2 Data Collection Process

Mass Points: The spacing of the grid pattern for mass point location will be determined by the required accuracy of the terrain model. For normal design work the spacing should be about 25 feet. If an area requires additional data to further define the terrain, such as low and high spots, then additional data points shall be collected at a smaller interval. The data point consists of “xyz” values. To identify a mass point for use in the GeoPak design software each point’s data shall include a feature code of 1 preceding the point's "xyz" values to identify the point as a mass point.

Breaklines: Breaklines shall be identified to locate linear terrain features that have a uniform slope on either side of the line. A breakline acts as a "hinge" for any triangulation that would pass through them. Any triangulation that tries to get past a breakline by going over or under it is forced to go up or down to that breakline and then continue on from there. This prevents the TIN from submarining through ridges or bridging over drains. Breaklines shall not cross or intersect each other. To identify a breakline for use in the GeoPak design software each breakline shall begin with a feature code of 2. All additional points along the breakline shall be identified by a feature code of 3.

Obscured Areas: There may be areas that are inaccessible to a survey crew or photogrammetric operator. These areas shall be outlined by a closed polygon around the area. The closed polygon whose vertices are at ground elevation, similar to a profile, actually becomes a breakline during processing of the DTM. All polygon points defining an obscured area shall begin with a feature code of 4.

Photogrammetry: If a DTM for a large area is required, it is more efficient to collect the data using photogrammetry techniques. The stereoplotter technician can quickly scan large areas of terrain and collect the required data points. The technician will first determine and plot all breaklines. After that, all open areas will be supplemented with mass points following a grid pattern.

Conventional Process: For small areas, the conventional process is more efficient. All mass points and break line points can be identified as outlined above.

C.3 How The Data Points Are Used

TIN Model: The data points are used to develop a Triangular Irregular Network (TIN) model. This model consists of a series of triangles established by using the mass points as vertices of the triangles. Each triangle is actually a plane surface with its slope defined by the three data points. The breaklines act as barriers that do not allow the formation of triangular planes across them. This provides a true representation of the ground surface.

Once the TIN model is developed, various centerline proposals can be studied very easily. Centerlines can be defined and intersected with the TIN model to determine the cross sections along a random centerline. From this information the cut and fill computations for design can be performed. If this determination is not satisfactory, a new alignment can easily be inserted and the results evaluated. The TIN model is a very handy tool for analyzing new design alignments.

Contours: If contours are required in the design phase, they can easily be developed from the TIN model using the proper software. Since the procedure is totally digital, any contour interval can be developed. The user must remember the source of the input data and not use the data beyond its established accuracy.

C.4 Transfer Of Data

All DTM collected data shall be transferred in an ASCII format. The format of the file is quite simple: a feature code followed by x, y, z coordinate values in succession. A single point record occupies each line of the ASCII file. Spaces serve as delimiters between individual fields.

The feature code is mandatory and informs GeoPak how to interpret the input records. An index shall be included with the data files explaining what data files are being transferred and what information they contain.

Please Note: IDOT has developed specific standards for collecting the DTM information. It is titled “Standards for the Collection of Data for Digital Terrain Models”. It is a part of the “Computer-Aided Design Drafting: Electronic Data Transfer Standards” document, dated March 2, 1998.

V. SPECIAL SURVEYS

A. BRIDGE

Surveys may include bridge surveys at railroad or highway grade separations, river and stream crossings. The following data shall be obtained by the survey crew in the field: alignment, vertical control, profiles and cross-sections, intersection angles, bridge data, topography, high water marks, direction of flow, stream bed profile and stream cross sections. See Chapter 2 of the Bureau of Bridges and Structures Drainage Manual for more details.

A.1 Alignment

Recover or reestablish the alignment points controlling the centerline of the existing roadway. Alignment control points should be placed far enough back from the structure to perpetuate the alignment for construction staking.

A.2 Vertical Control

Give the location, elevation and description of the bench mark used in the survey. All elevations should be referenced to the North American Vertical Datum of 1988 (NAVD88) unless otherwise specified. Bench marks should be set to meet third-order accuracy.

A.3 Profile and Cross-Sections

Profile the roadway centerline 600 feet (200 meters) each way from the bridge center. A cross-section should be taken parallel to the centerline and offset 50 to 100 feet (15 to 30 meters) from the structure upstream and downstream.

Cross-sections are needed at 100 foot (25 meter) intervals and should extend left and right of the centerline a distance far enough to cover the high water marks or any proposed height increase of the roadway. Sufficient “plus” stations should be taken to show the design engineer the shape of any fill around the structure.

At grade separations between railroads and roadways, profile the top of the rails 300 feet (100 meters) each side of the bridge.

A.4 Intersection Angles

Determine the intersection angle between roadway centerline and base line of the railroad, stream, etc.

Where a stream has a rather irregular course in the vicinity of the highway centerline and where there is some question as to the location of the bridge, the stream should be located accurately for some distance on each side of the centerline, either by stadia or by measuring offsets to the base line.

A.5 Bridge Data

The survey crew should record the performance of existing structures. Information on existing structures may be obtained from local residents and the District Bureau of Operations in addition to the physical field survey. This information should be obtained for the adjacent structures upstream and downstream as well as the structure at the site.

Data at existing structures should include the following, if available:

- Date of construction.
- Major flood events since construction.
- Performance during past floods.
- Scour indicated near the structure.
- Type of material in streambeds and banks.
- Condition of structure.
- Alignment and general description of structure including dimensions and elevations.
- A sketch of the structure should be made to illustrate the features.
- Size and shape of waterway opening.
- High water elevations with datum and dates of occurrence.
- Location and description of overflow areas.
- Photographs.
- Silt and draft accumulation.
- Evidence of headcutting in stream.

A.6 Topography

Topography 500 feet (150 meters) left and right of the roadway centerline for a distance of 600 feet (200 meters) from the center of the bridge should be recorded.

A.7 High and Low Water Stages

High and low water information should be noted along with the source of the information.

A.8 Direction of Flow

The direction of the stream flow should be shown on the sketch along with a north arrow.

A.9 Streambed Profile and Cross-Sections

Obtain elevations in the bottom of the streambed for 1000 feet (300 meters) upstream and downstream. Take four typical stream cross-sections about 500 feet (150 meters) and 1000 feet (300 meters) both upstream and downstream from an existing bridge centerline. The cross-sections should extend 3 feet (1 meter) above the 100 year flood plain elevation, be normal to stream flow and other locations that may affect the design of a proposed bridge. Due to the meandering tendency of most of our stream systems, it is extremely difficult to locate a representative section that is at right angles to both the low flow channel and the flood plain. Proper sectioning of these locations requires surveying across the flood plain at right angles, then pivoting at the channel bank to shoot at right angles across the channel, and then pivoting again by swinging the angle necessary to continue across the flood plain normal to the direction of flow. An alternate procedure is to shoot across the flood plain and channel on a straight line properly recording the skew of the flood plain and channel so that the designer can make the necessary dimensional adjustments in the office.

B. DRAINAGE

Hydrology is the science of properties and distribution of water on the surface of the land. In highways we are most concerned with the amount of water which runs off the land surface and its effect on the design of highway drainage structures. Survey notes of drainage information shall contain the location and elevation of ditches, waterways, inlets and outlets of culverts, tile lines, catch basins and manholes. Location information of any adjacent wetlands shall also be noted.

B.1 Rural Drainage

Measure the flow lines of all culverts and ditches for a distance of not less than 100 feet (30 meters) on each side of the centerline. Readings should be taken on a cross-section of a culvert at the top of the opening, on the dirt flow line (if the culvert is partially filled with dirt or other debris) and also on the bottom of the culvert at both ends. If the culvert has a "broken" flow line, this detail must be shown. The size of the culvert shall also be measured and recorded along with the type. A typical cross-section should be taken upstream and downstream and at right angles to the natural waterway or ditch. Tile lines shall be located where they will be affected by construction. Tie the tile line to the horizontal and vertical datums to provide design the necessary information to perpetuate the existing tile system.

B.2 Urban Drainage

Research for survey data for in-place sewer systems should be made with municipalities for layout maps of the system. Additional information may be acquired from abutting property owners and business places along the project. Record this information in field notes along with names of persons and phone numbers for future contact.

C. HISTORICAL SITES PRESERVATION

Historical sites identified in project reports shall be tied into the project coordinate system to show limits relative to the project corridor. A land survey should also be done to locate the true boundary location of the site.

D. NOISE BARRIERS

Surveys of noise barriers shall include base line alignment, and topography.

D.1 Base Line

The base line is a random line run as parallel as possible to the proposed wall. Do not use any curves in the base line. Base line should be located based on project coordinates.

D.2 Cross-Sections

Cross-sections are to be taken at 100 foot (25 meter) intervals on the base line and extend outward far enough to cover the proposed area.

D.3 Topography

Topography is an essential item in wall design. Overhead wires and underground utilities are critical and need to be referenced to the base line.

E. OVERLAYS

Overlay surveys are made to perpetuate in-place alignments, perpetuate the Public Land System and private property monuments and provide information to the designer.

E.1 Alignment

The construction and the right of way centerlines should be recovered. If they are not the same centerline, it is important to the general public to monument the right of way centerline.

E.2 Perpetuation of Public Land Survey (PLS) Corners

It is important to protect the public rights in property corner maintenance. All PLS corner monuments should be located, extended to the surface, monumented and monument records recorded.

E.3 Design Information

The designer needs some basic information to use in developing overlay construction plans.

E.3.1 Cross-Sections

Typical cross-sections are needed at random locations to show existing pavement and shoulder widths. Profiles and/or cross-sections may be needed by the designer for quantity computation at locations like culverts, bridge approaches, railroad crossings, etc. It is a good idea to review with the designer what data is needed on a particular project.

E.3.2 References

Stationing ties should be made to locate crossroads, entrances, guard rails, entrance culverts, box culverts, etc.

E.3.3 Encroachments

Make notes on any apparent encroachments on the state right of way.

E.3.4 Utilities

Make reference ties to all utilities that may be affected, such as manholes, catch basins, etc.

F. PIPELINES

There are four data items to be examined when gathering information on pipelines for the designer: ownership, product transported, pipeline material and its location.

F.1 Ownership

All pipelines are marked in the field with identifying signs showing ownership. Permits are on file in the district office that will state the ownership at the time of pipeline construction.

F.2 Product Transported

There are three general classifications of pipelines: oil, gas and commodity.

F.2.1 Oil

These pipelines transport only crude oils from the oil field to the refinery.

F.2.2 Gas

These pipelines transport natural gas under high pressure.

F.2.3 Commodity

These pipelines may transport products such as liquefied petroleum gas, liquid fertilizers, and anhydrous ammonia.

F.3 Pipeline Location and Material

The pipeline company can provide general details of the line and right of way or easement widths in the area being surveyed. If a detailed survey is required, arrangements can be made to meet their locating crew at the site. The pipeline crew will do all location work. The IDOT survey crew will determine the following: coordinates, elevations, materials and vent locations.

F.3.1 Coordinates

Reference the pipeline location to project coordinates by traverse procedures.

F.3.2 Elevations

Obtain the elevation of the top of pipe if possible and the elevation of the ground.

F.3.3 Materials

Record the size and type of pipe. For example: 3 inches (0.076 meters) steel, 2 inches (0.050 meters) plastic, etc. Also provide operating pressure information.

F.3.4 Vents

Determine the size of vents and tie in the ends of the pipes.

G. PITS

When performing a pit survey, permanent horizontal and vertical control points or monuments should be set. Some pits may be used for many years and subsequent surveys must be tied to the original datum.

G.1 Control

Two permanent bench marks should be established for each pit. They should be referenced to the North American Vertical Datum of 1988 (NAVD88). Horizontal control monuments should be established by tying them to the project coordinates or highway alignment.

G.2 Cross-Sections

Cross-section the entire pit area on a grid not to exceed 100 feet (25 meters) and extend the cross-section a minimum of 100 feet (25 meters) beyond the boundary of the pit.

G.3 Bottom Elevation

If the pit site is an existing pit, take enough elevation readings to depict the elevation of the bottom of the pit.

G.4 Water Information

Survey the perimeter, elevation and depth of any standing water in an existing pit. This may require the use of a boat and an electronic sounding device if the water is very deep.

H. RAILROADS

A survey is required where a highway is constructed parallel or adjacent to a railroad or where a highway and a railroad intersect. The survey shall reference the railroad rails to the highway centerline.

H.1 Alignment

Recover or reestablish the alignment points controlling the centerline of the existing or proposed highway and the centerline of the railroad. Usually the center of the rails is the centerline of the right of way for single track railroads. For multiple track railroads, the center of one of the mainline tracks is usually the centerline for the railroad right of way. Make at least three reference ties to all alignment points. At all railroad crossings a “plus” to the nearest one tenth of a foot (0.030 meters) is needed on the inside edge of each rail.

H.2 Vertical Control

Record the location, elevation and description of the bench marks used in the survey. A profile of each rail should be obtained to the nearest one hundredth of a foot (0.003 meters) for at least 1000 feet (300 meters) on each side of the highway centerline in cases where a grade separation is planned. Where there is to be a grade crossing, the rail profiles should be obtained for a distance of 300 feet (100 meters) on each side of the centerline.

H.3 Intersection Angles

If the tracks are on a tangent for some distance on each side of the centerline, the angle between the tracks and the highway centerline should be obtained. If the tracks are on a curve, angles to the line of one rail are required at 50 foot (20 meter) intervals for a distance of 200 feet (60 meters) on each side of the centerline, and at 150 foot (50 meter) intervals for an additional distance of 500 feet (150 meters) for a total distance of 700 feet (210 meters). The intersection of the highway centerline and the railroad centerline is to be tied to the nearest railroad milepost and the number of the post given. The name of the railroad should also be noted.

H.4 Crossings

The type, width and condition of existing railroad crossings should be noted along with the type and location of the warning signs and signals. All pole lines along the railroad within a distance of 300 feet (100 meters) should be recorded and ownership noted.

I. SIGNAL - TRAFFIC

A signal survey is basically a utility survey and is usually needed where traffic signals are to be installed or upgraded in an urban area.

I.1 Required Data

I.1.1 Topography

The location and ownership of all in-place underground utilities should be surveyed.

I.1.2 Elevations

Elevations of the centerline of the traveled roadway opposite the proposed signal base is required if the signal is to be an overhead type.

I.1.3 Cross-Sections

A partial cross-section may be needed instead of the single vertical elevation if the area where the signal base is to be placed has a steep slope or large vertical difference from the centerline.

J. TURN LANES

Data required for turn lanes includes elevations, topography and cross-sections.

J.1 Elevations

The North American Vertical Datum of 1988 (NAVD88) should be used as the reference datum for all elevations.

J.2 Topography

A complete topographic survey is required of each turn lane location. Data should include information on all obstacles within the clear zone, such as, road culverts, utilities, local road names and signs that need to be moved.

J.3 Cross-Sections

Cross-sections taken will depend upon the terrain at the site. In flat rural areas two would be enough to compute quantities; whereas in a built up urban area, or other complex area, a full set of may be needed.

K. UTILITIES

Utility surveys shall include the location and elevations of all utilities located in the vicinity of any proposed highway project. To avoid construction damages, delays and claims, it is imperative that all in-place utility facilities are identified, located and shown on construction plans.

K.1 Alignment

Recover or reestablish survey centerline control points. Utilities should be referenced to the centerline and the project coordinate system.

K.2 Elevations

Obtain the elevation of the top of inlets, inverts, flow lines and bottoms of all man holes, flow lines of culverts, sanitary and storm sewers. Note the depth of any cable, conduit or water line. **PLEASE NOTE: The Department has a Confined Space Policy that requires survey crews to take extensive safety measures when performing inspections or surveys of sewers, inlets, manholes and culverts.** See Appendix D for the details of the Confined Space Policy.

K.3 Topography

Show the size, type of construction and the condition of the in-place utility facility. When an underground facility is located by the utility company, note the date and name of the person who did the location and the name and address of the utility company.

K.4 Profiles and Cross-Sections

Take profile and cross-sections as needed for the determination of any required grade changes and the determination of construction quantities when the utility is to be relocated.

L. PRELIMINARY STAKING

There are several circumstances where the preliminary staking of a proposed improvement may be required. One of these is the staking required for the “plan in hand” field check. When staking for the field check, lath or other highly visible, temporary markers should be placed on centerline at convenient locations such as fence lines and borders of timbered areas. Intermediate markers may be placed at 1000 feet (300 meter) intervals if no crop damage will result or their presence will not interfere with farming operations. It is recommended that markers be provided with colored plastic tape or other devices to increase their visibility. Markers should also be placed on alignments of channel changes and public road relocations. At interchange areas, sufficient marking should be provided to delineate the outermost ramps. In addition, markers to identify the proposed right of way limits should be provided at interchanges, built-up areas or other locations where right-of-way is critical. Requirements for staking in urban areas may be modified as required to provide as much of the alignment information previously noted as permitted by existing development.

Example of recording stations "ties".

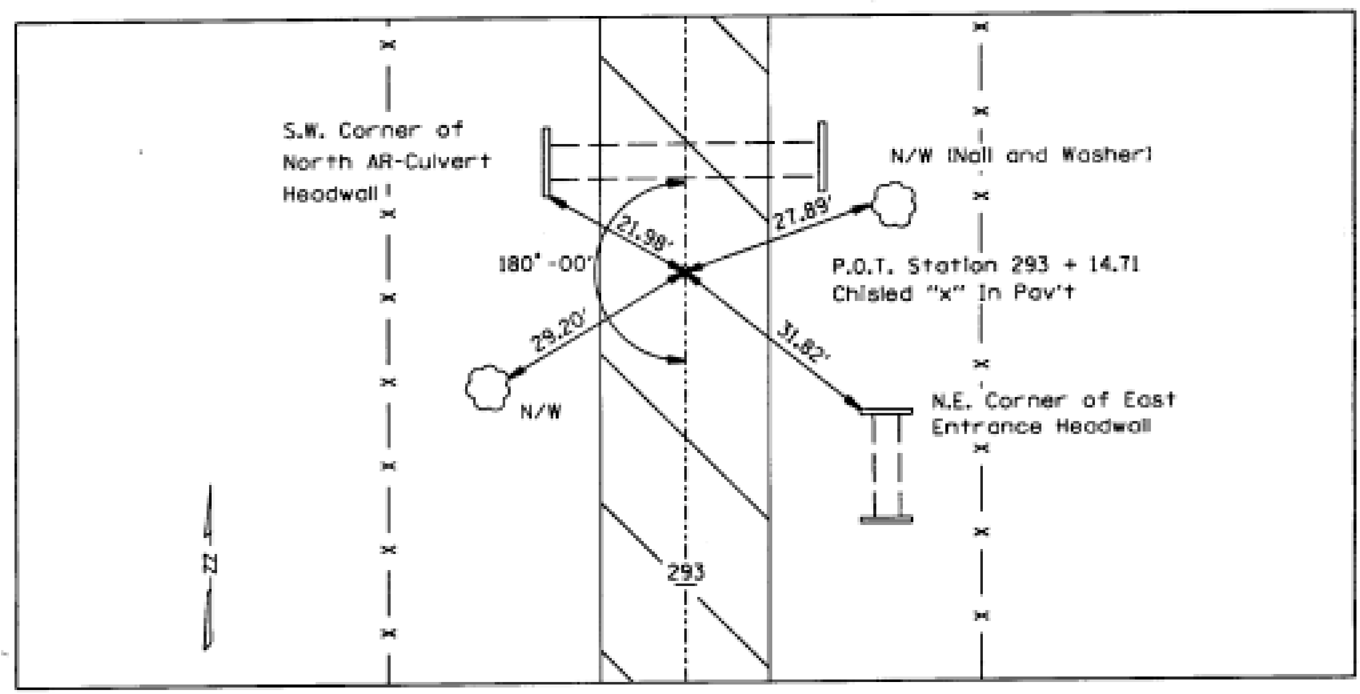

Figure 3.1

40

9533				748.943	
	6.783				
	4.354		3.112		
3034			4.133	752.835	PK & W in ℄ PVT @ CTR of Box Culv.
	3.823				
	6.423		4.625		
3033			1.577	756.879	PK & W in ℄ PVT.
	7.925				
	8.504		0.708		
	7.976		1.847		
9532			2.246	776.483	CHIS Δ on SW ISLAND & PAINTED X
	3.821				
432			3.884	776.420	SET CHIS "□" on Bottom Step of sidewalk SW'ly from 9532
	4.850				
3037			4.843	776.427	PK & W @ ℄-℄ of IL. 26 & US Rte 30
	3.954				
	2.100		6.636		
	3.293		5.680		
	2.575		6.026		
3032			5.303	764.704	PK & W in ℄ PVT. opp. Pine Tree

Figure 3.2

USED WILD NA2002 ELECTRONIC LEVEL

D-1902
E96
4/16/96

P-92-055-
90
BIGXEXT

"ALL TURN POINTS ARE P.K. NAILS IN SHOULDER"

POINT #	B.S.	F.S.	DIST.	ELEV.	DESCRIPTION
TBM 2	0	0	0	**701.0173**	CHISELED SQ ON S. HDWL
TBM 2	5.5581	0	68.4710		
9601	0	6.6562	67.1587		
9601	0	0	0	**699.9192**	TOP OF 60d
9601	8.8697	0	161.7451	0	
32	0	-0.0154	254.3630	0	
32	0	0	0	**708.8043**	P. K. NAIL
32	9.0649	0	201.9025	0	
3001	0	3.3684	161.9419	0	
3001	0	0	0	**714.5008**	TOP OF 60d
3001	8.3914	0	218.3723	0	
9502	0	1.2283	295.6687	0	
9502	0	0	0	**721.6639**	P. K. NAIL
9502	7.3261	0	232.1190	0	
33	0	3.5121	253.9693	0	
33	0	0	0	**725.4779**	P. K. NAIL
33	6.1437	0	193.6020	0	
3002	0	6.4862	207.9392	0	
3002	0	0	0	**725.1354**	TOP OF 60d
3002	7.0853	0	267.1254	0	
TBM 12	0	5.5312	102.3292	0	
TBM 12	0	0	0	**726.6895**	P. K. NAIL
TBM 12	4.8779	0	243.9300	0	
1	0	5.8396	244.4877	0	
1	0	0	0	**725.654**	P. K. NAIL
1	4.9967	0	242.9129	0	
2	0	5.9134	246.9155	0	

Figure 3.2a

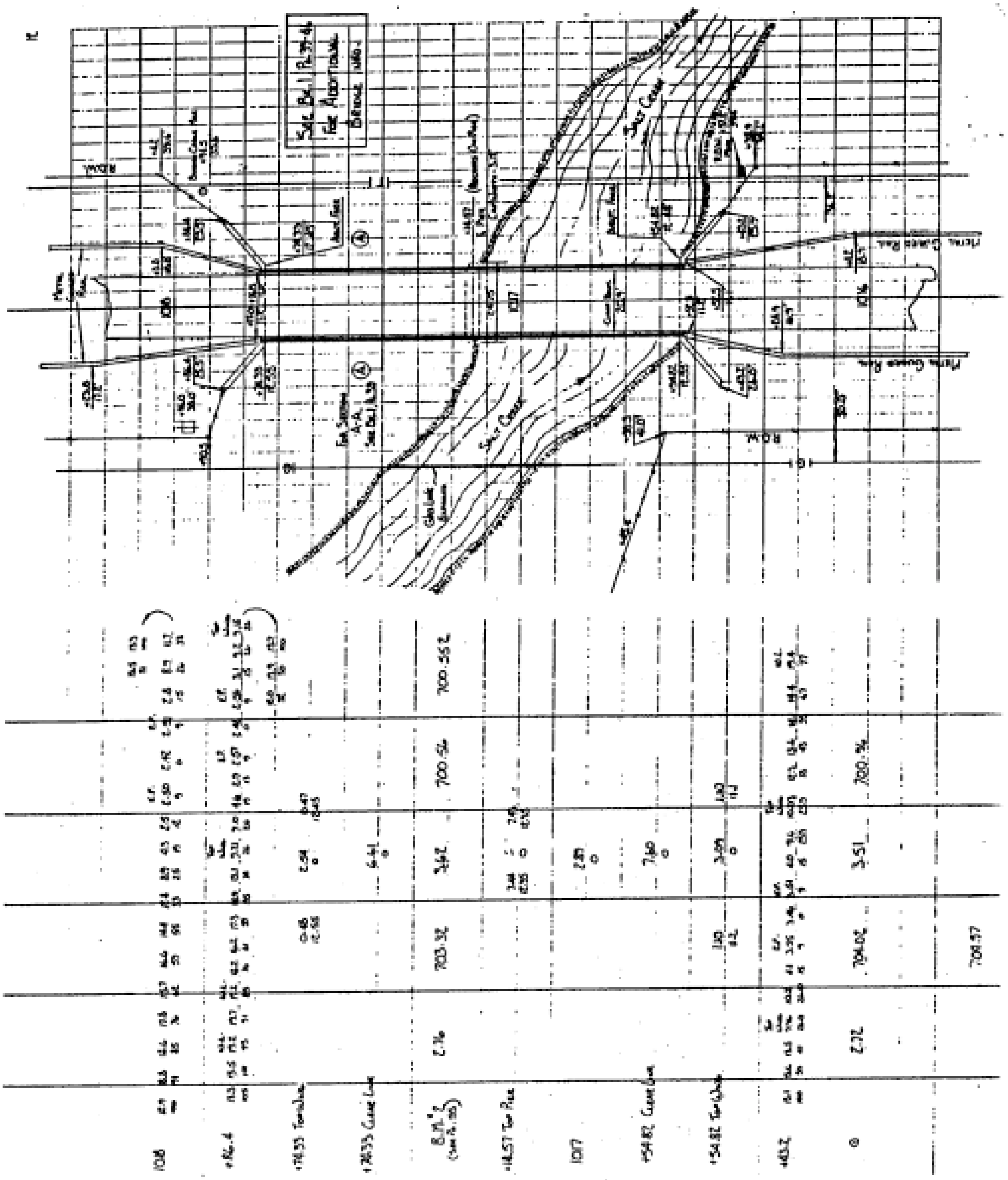

Figure 3.3a

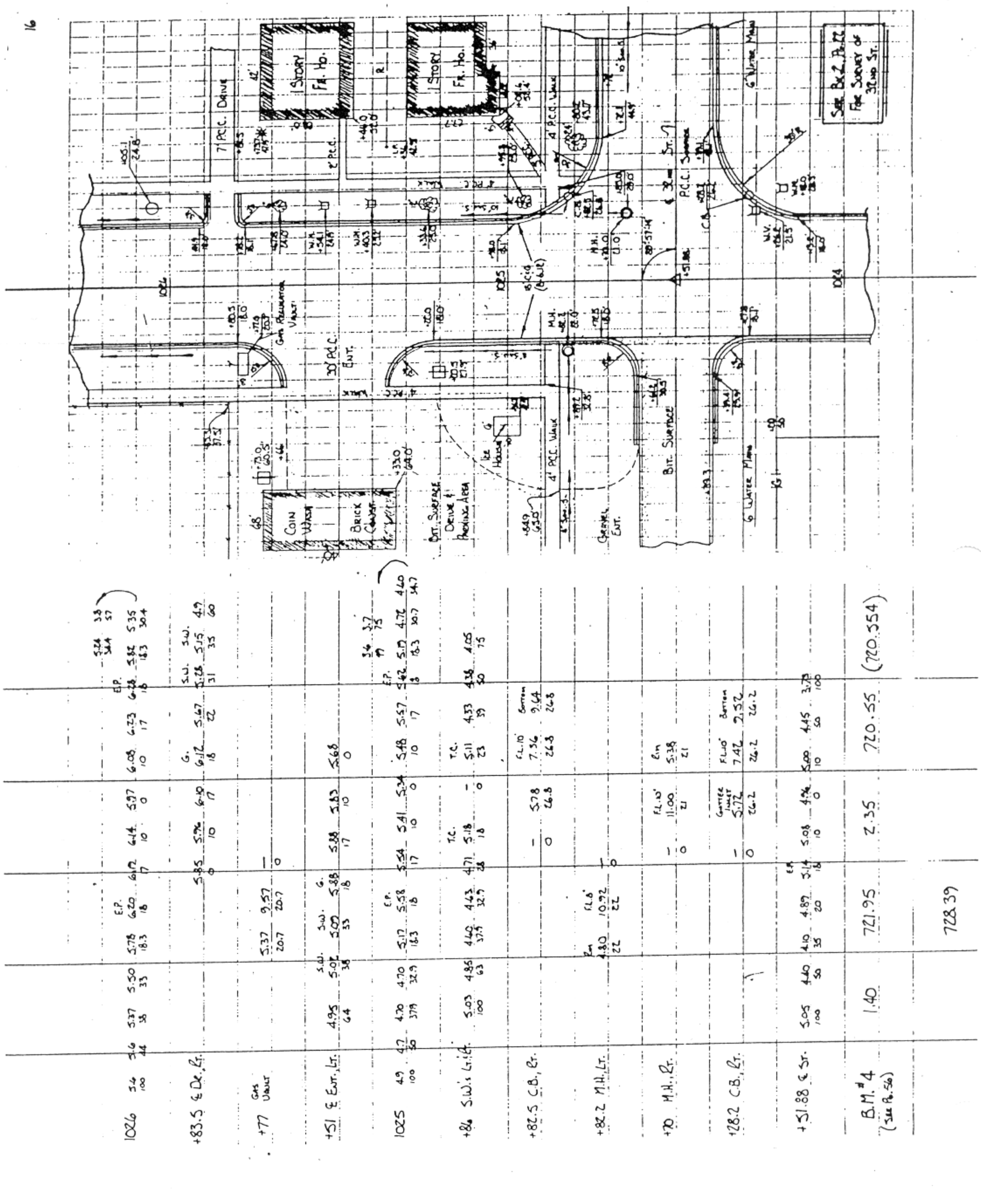

Figure 3.3b

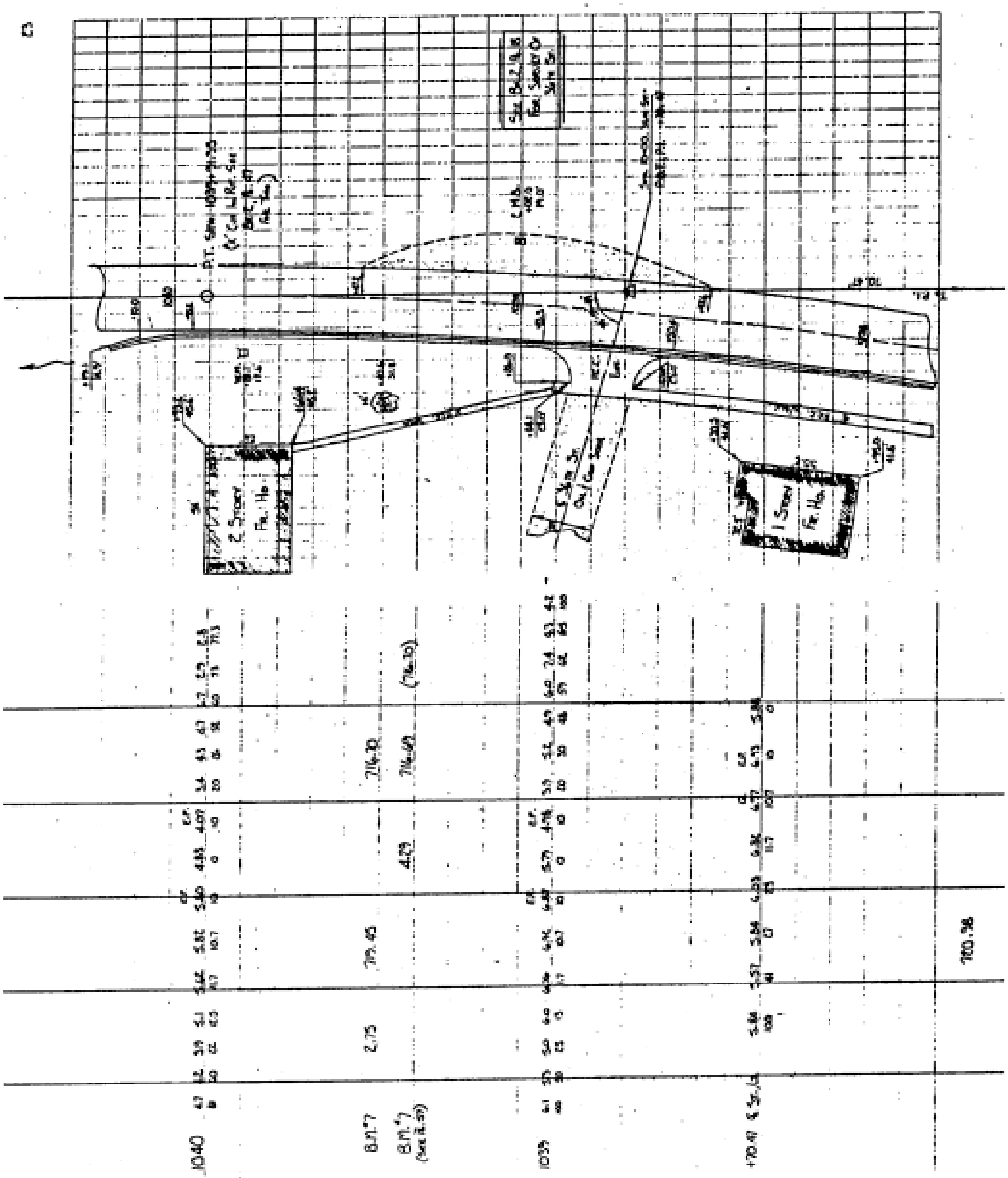

Figure 3.3c

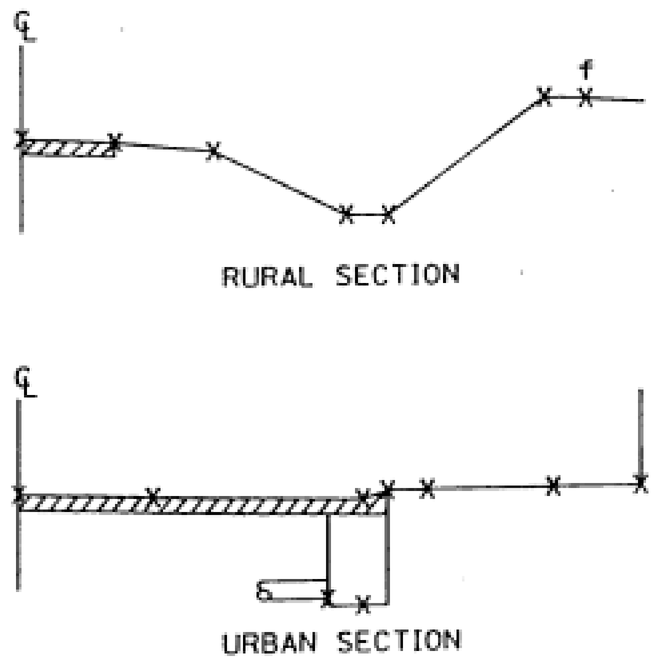

Figure 3.4

TABLE OF DEFLECTIONS
for
Various Radii and Arc Lengths

RADIUS (feet)	DEFLECTIONS IN MINUTES Per Foot of Arc	DEFLECTIONS FOR ARCS OF 25 feet			50 feet			100 feet		
		°	'	"	°	'	"	°	'	"
50	34.3775	14	19	26	28	38	52	57	17	45
60	28.6479	11	56	12	23	52	24	47	44	47
70	24.5553	10	13	53	20	27	46	40	55	32
80	21.4859	8	57	9	17	54	18	35	48	36
90	19.0986	7	57	28	15	54	56	31	49	52
100	17.1887	7	9	43	14	19	26	28	38	52
125	13.7510	5	43	46	11	27	33	22	55	6
150	11.4592	4	46	29	9	32	57	19	5	55
175	9.8221	4	5	33	8	11	6	16	22	13
200	8.5944	3	34	52	7	9	43	14	19	26
225	7.6394	3	10	59	6	21	58	12	43	57
250	6.8755	2	51	53	5	43	46	11	27	33
275	6.2504	2	36	16	5	12	31	10	25	3
300	5.7296	2	23	14	4	46	29	9	32	57
325	5.2888	2	12	13	4	24	27	8	48	53
350	4.9111	2	2	47	4	5	33	8	11	6
375	4.5837	1	54	35	3	49	11	7	38	22
400	4.2972	1	47	26	3	34	52	7	9	43
425	4.0444	1	41	7	3	22	13	6	44	26
450	3.8197	1	35	30	3	10	59	6	21	58
475	3.6187	1	30	28	3	0	56	6	1	52
500	3.4377	1	25	57	2	51	53	5	43	46
550	3.1252	1	18	8	2	36	16	5	12	31
600	2.8648	1	11	37	2	23	14	4	46	29
650	2.6444	1	6	7	2	12	13	4	24	27
700	2.4555	1	1	23	2	2	47	4	5	33
750	2.2918	0	57	18	1	54	35	3	49	11
800	2.1486	0	53	43	1	47	26	3	34	52
850	2.0222	0	50	33	1	41	7	3	22	13
900	1.9099	0	47	45	1	35	30	3	10	59
950	1.8093	0	45	14	1	30	28	3	0	56
1000	1.7189	0	42	58	1	25	57	2	51	53
1100	1.5626	0	39	4	1	18	8	2	36	16
1200	1.4324	0	35	49	1	11	37	2	23	14
1300	1.3222	0	33	3	1	6	7	2	12	13
1400	1.2278	0	30	42	1	1	23	2	2	47
1500	1.1459	0	28	39	0	57	18	1	54	35
1600	1.0743	0	26	51	0	53	43	1	47	26
1700	1.0111	0	25	17	0	50	33	1	41	7
1800	0.9549	0	23	52	0	47	45	1	35	30
1900	0.9047	0	22	37	0	45	14	1	30	28
2000	0.8594	0	21	29	0	42	58	1	25	57
2100	0.8185	0	20	28	0	40	56	1	21	51
2200	0.7813	0	19	32	0	39	4	1	18	8

$$d \text{ (in minutes)} = \frac{1718.873 \times \text{ARC LENGTH (FT)}}{\text{RADIUS (FT)}}$$

RADIUS (feet)	DEFLECTIONS IN MINUTES Per Foot of Arc	DEFLECTIONS FOR ARCS OF 25 feet			50 feet			100 feet		
		°	'	"	°	'	"	°	'	"
2300	0.7473	0	18	41	0	37	22	1	14	44
2400	0.7162	0	17	54	0	35	49	1	11	37
2500	0.6875	0	17	11	0	34	23	1	8	45
2600	0.6611	0	16	32	0	33	3	1	6	7
2700	0.6366	0	15	55	0	31	50	1	3	40
2800	0.6139	0	15	21	0	30	42	1	1	23
2900	0.5927	0	5	56	0	8	53	0	14	49
3000	0.5730	0	5	44	0	8	36	0	14	19
3100	0.5545	0	5	33	0	8	19	0	13	52
3200	0.5371	0	5	22	0	8	3	0	13	26
3300	0.5209	0	5	13	0	7	49	0	13	1
3400	0.5056	0	5	3	0	7	35	0	12	38
3500	0.4911	0	4	55	0	7	22	0	12	17
3600	0.4775	0	4	46	0	7	10	0	11	56
3700	0.4646	0	4	39	0	6	58	0	11	37
3800	0.4523	0	4	31	0	6	47	0	11	19
3900	0.4407	0	4	24	0	6	37	0	11	1
4000	0.4297	0	4	18	0	6	27	0	10	45
4100	0.4192	0	4	12	0	6	17	0	10	29
4200	0.4093	0	4	6	0	6	8	0	10	14
4300	0.3997	0	3	60	0	5	60	0	9	60
4400	0.3907	0	3	54	0	5	52	0	9	46
4500	0.3820	0	3	49	0	5	44	0	9	33
4600	0.3737	0	3	44	0	5	36	0	9	21
4700	0.3657	0	3	39	0	5	29	0	9	9
4800	0.3581	0	3	35	0	5	22	0	8	57
4900	0.3508	0	3	30	0	5	16	0	8	46
5000	0.3438	0	3	26	0	5	9	0	8	36
5100	0.3370	0	3	22	0	5	3	0	8	26
5200	0.3306	0	3	18	0	4	57	0	8	16
5300	0.3243	0	3	15	0	4	52	0	8	6
5400	0.3183	0	3	11	0	4	46	0	7	57
5500	0.3125	0	3	8	0	4	41	0	7	49
5600	0.3069	0	3	4	0	4	36	0	7	40
5700	0.3016	0	3	1	0	4	31	0	7	32
5800	0.2964	0	2	58	0	4	27	0	7	25
5900	0.2913	0	2	55	0	4	22	0	7	17
6000	0.2865	0	2	52	0	4	18	0	7	10
6500	0.2644	0	2	39	0	3	58	0	6	37
7000	0.2456	0	2	27	0	3	41	0	6	8
7500	0.2292	0	2	18	0	3	26	0	5	44
8000	0.2149	0	2	9	0	3	13	0	5	22
9000	0.1910	0	1	55	0	2	52	0	4	46
10000	0.1719	0	1	43	0	2	35	0	4	18
11000	0.1563	0	1	34	0	2	21	0	3	54
12000	0.1432	0	1	26	0	2	9	0	3	35
13000	0.1322	0	1	19	0	1	59	0	3	18
14000	0.1228	0	1	14	0	1	50	0	3	4
15000	0.1146	0	1	9	0	1	43	0	2	52